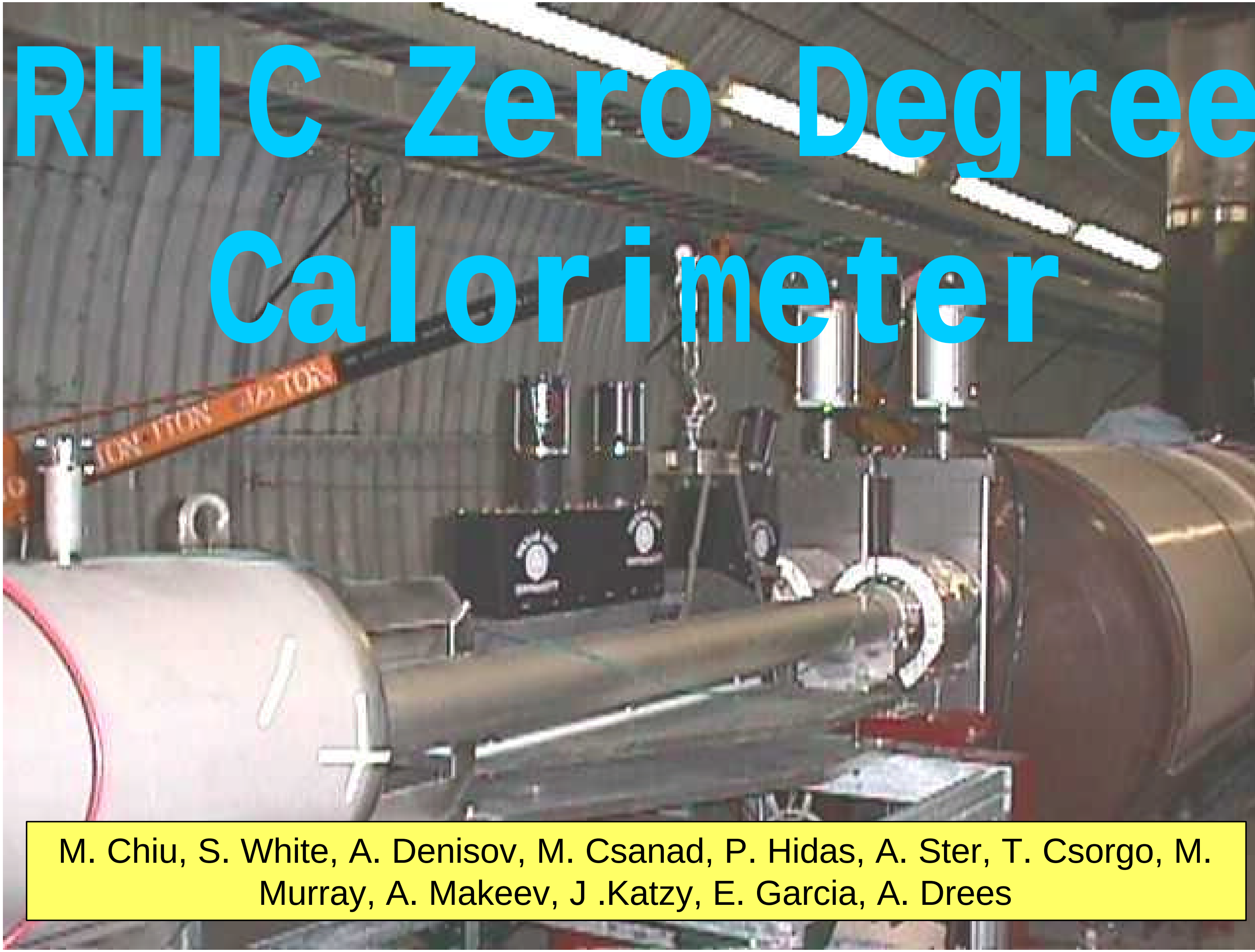
RHIC Zero Degree Calorimeter

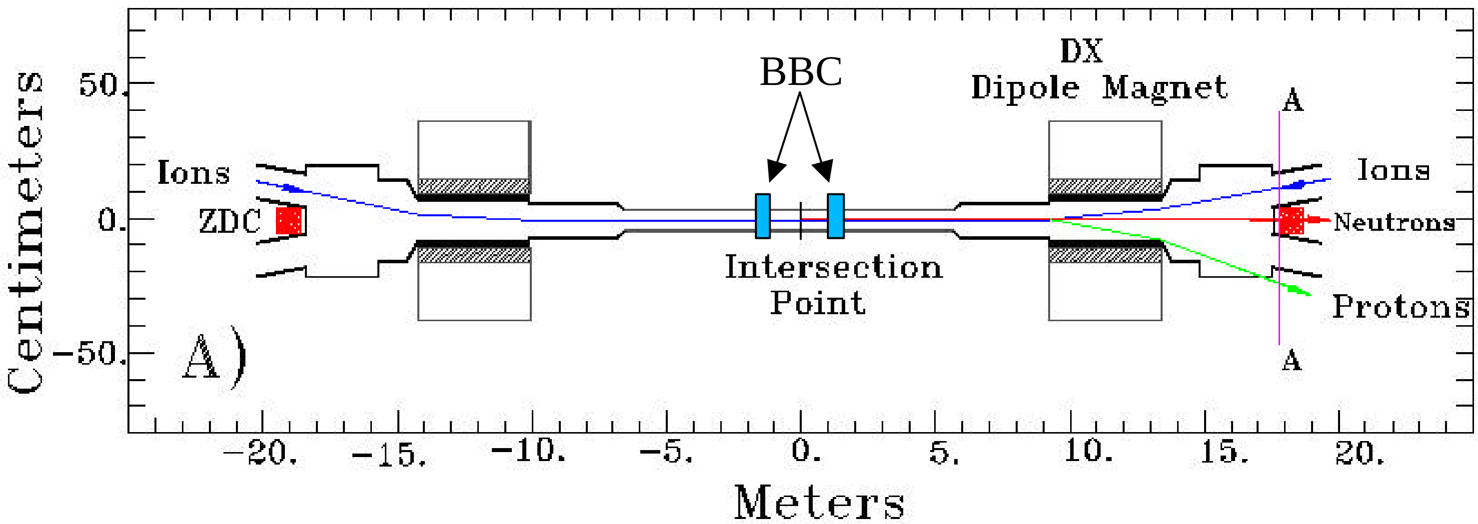


M. Chiu, S. White, A. Denisov, M. Csanad, P. Hidas, A. Ster, T. Csorgo, M. Murray, A. Makeev, J .Katzy, E. Garcia, A. Drees

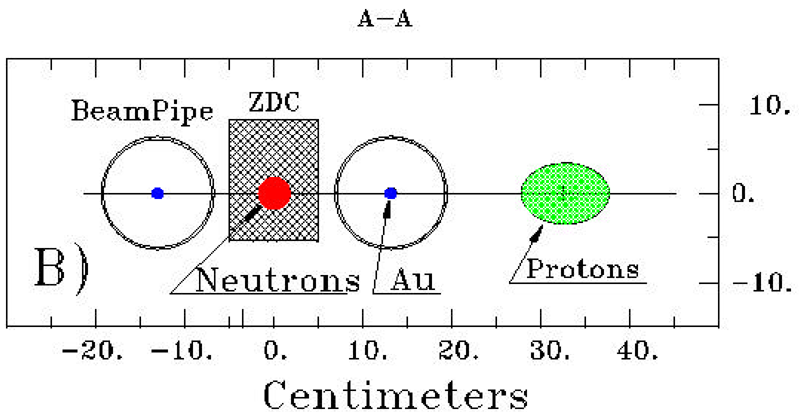
The ZDC is a Good Place to Be..

- Luminosity/Cross-Sections
  - $R = L\sigma$
- Event Characterization
  - Centrality (Au+Au, d+Au)
  - Event Vertex and Start-Time
  - Hadronic/Non-Hadronic (Au+Au, d+Au, p+p)
- Clean Triggering
- Ultra-Peripheral Coherent Interactions
- Transverse Spin Asymmetries
  - Local Polarimeter
- Relative Luminosity
  - Crucial for A_{LL}

Location, Location, Location

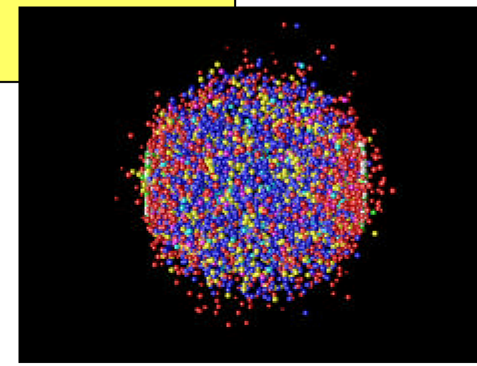


- There is a lot of physics at forward rapidities
- In a collider, you need to have a DX magnet to steer bunches so they collide
    - Spatial Distribution of Charged Particles shown below
- Large Separation = Easy Timing = Very Clean Trigger against Beam Gas and Beam Scrape



Collider Processes

- You're probably familiar with the "Hadronic Interactions"
- When colliding large nuclei, the Z creates a large photon flux
  - ZDC exploits this for a luminosity measurement
  - Also interesting physics (UCP program)



Hadronic Interaction

Hadronic Interaction:

Au-Au --> X 6.8 barns

γ-γ:

AuAu --> AuAu + e^+e^- 33 kbarns

AuAu --> AuAu + 2(e^+e^-) 680 barns

AuAu --> AuAu + 3(e^+e^-) 50 barns

γ-N: L(γ-N)=10^{29} $cm^{-2}s^{-1}$ 2<Eγ<300GeV

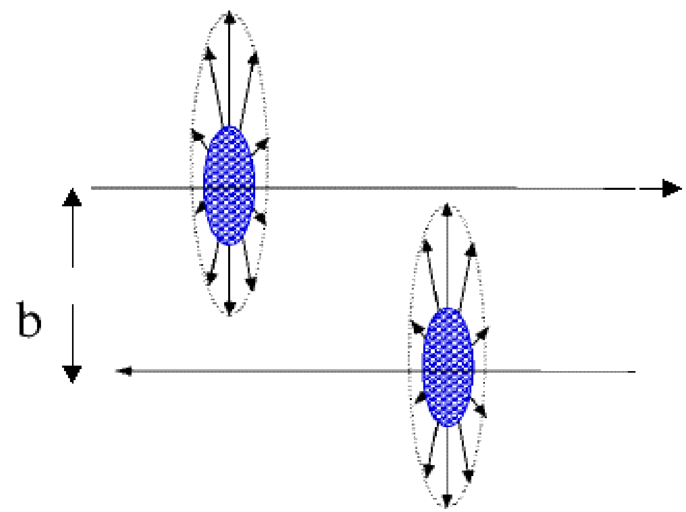
AuAu --> Au+Au* 92 barns

→ X+neutrons

AuAu --> Au*+Au* 3.67±0.26 barns

→ X+neutrons

→ Y+neutrons

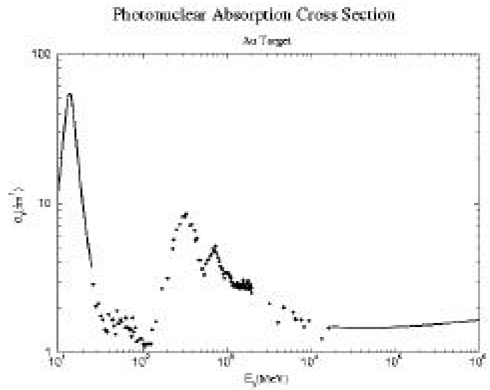


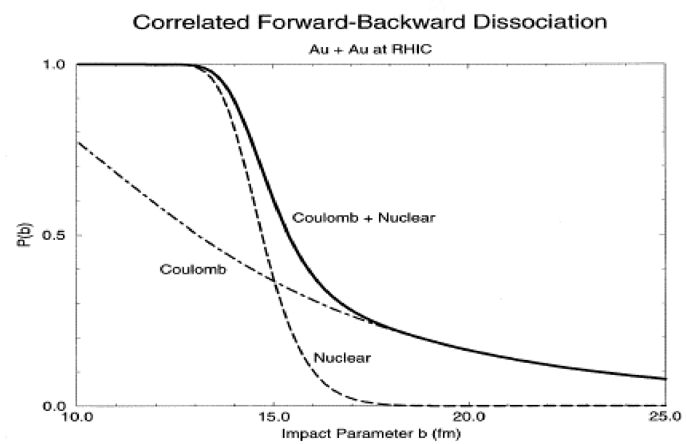
Peripheral Interaction

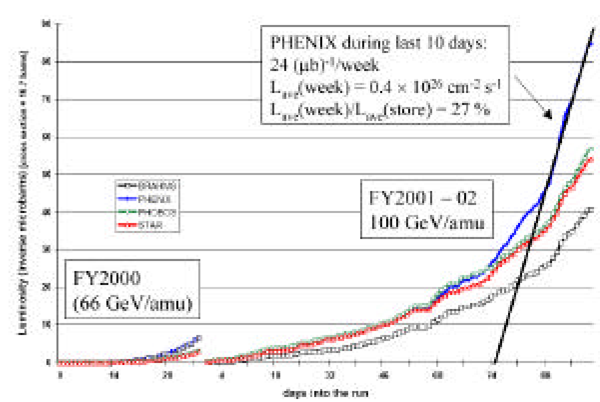
Total Cross-Section

NIM A 417:1-8,1998, nucl-ex/9801002

- Use Weiszacker-Williams to calculate equivalent photon flux
    - ie, Fourier Transform EM field to get photons
    - idea first put forth by Fermi
- Take measured photon dissociation data
- Key Point: Integrate through the nuclear radius to reduce uncertainty in lower cutoff for peripheral collisions
- Calculated Cross-Section good to 5%
    - 10.7 barns at root-s = 130 GeV
    - 11.0 barns at root-s = 200 GeV
    - But measurement is pristine

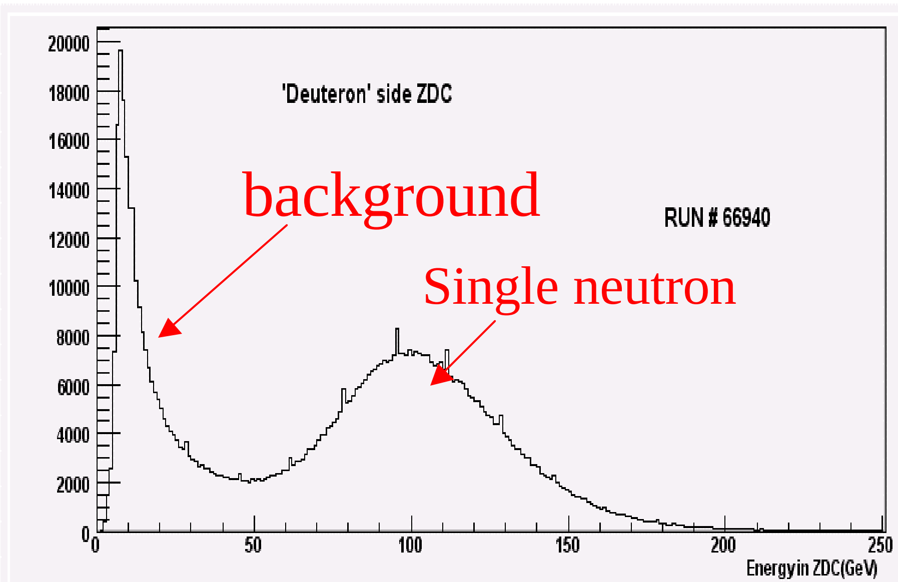


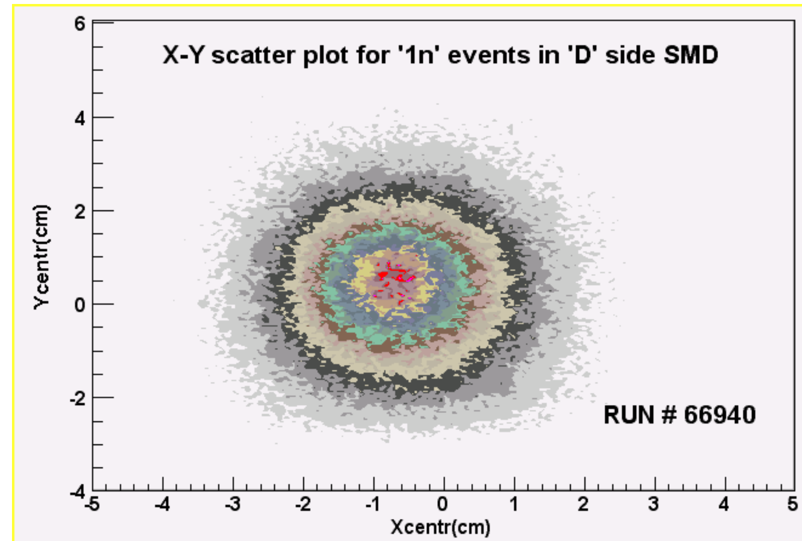




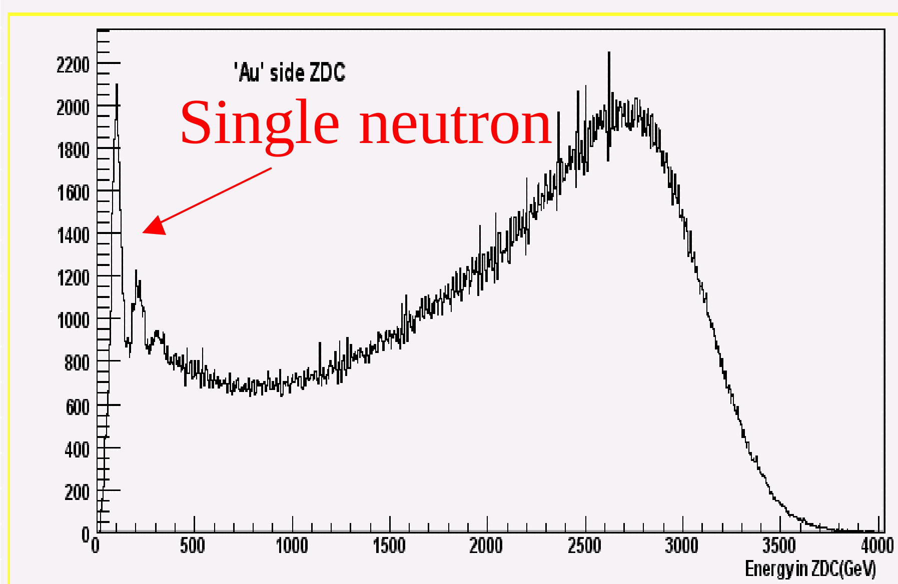
Energy and Spatial distribution in ZDC for d+Au @ 100Gev

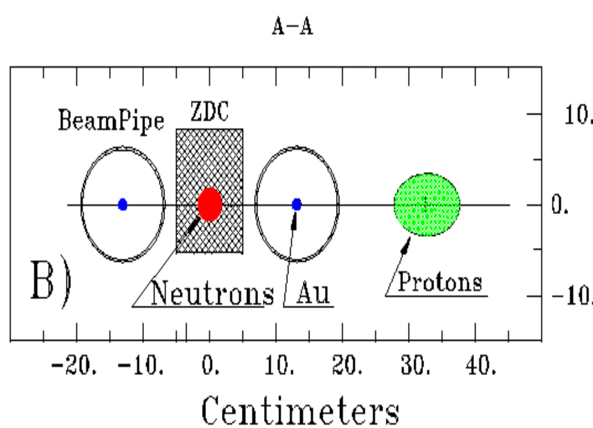
New in Run03



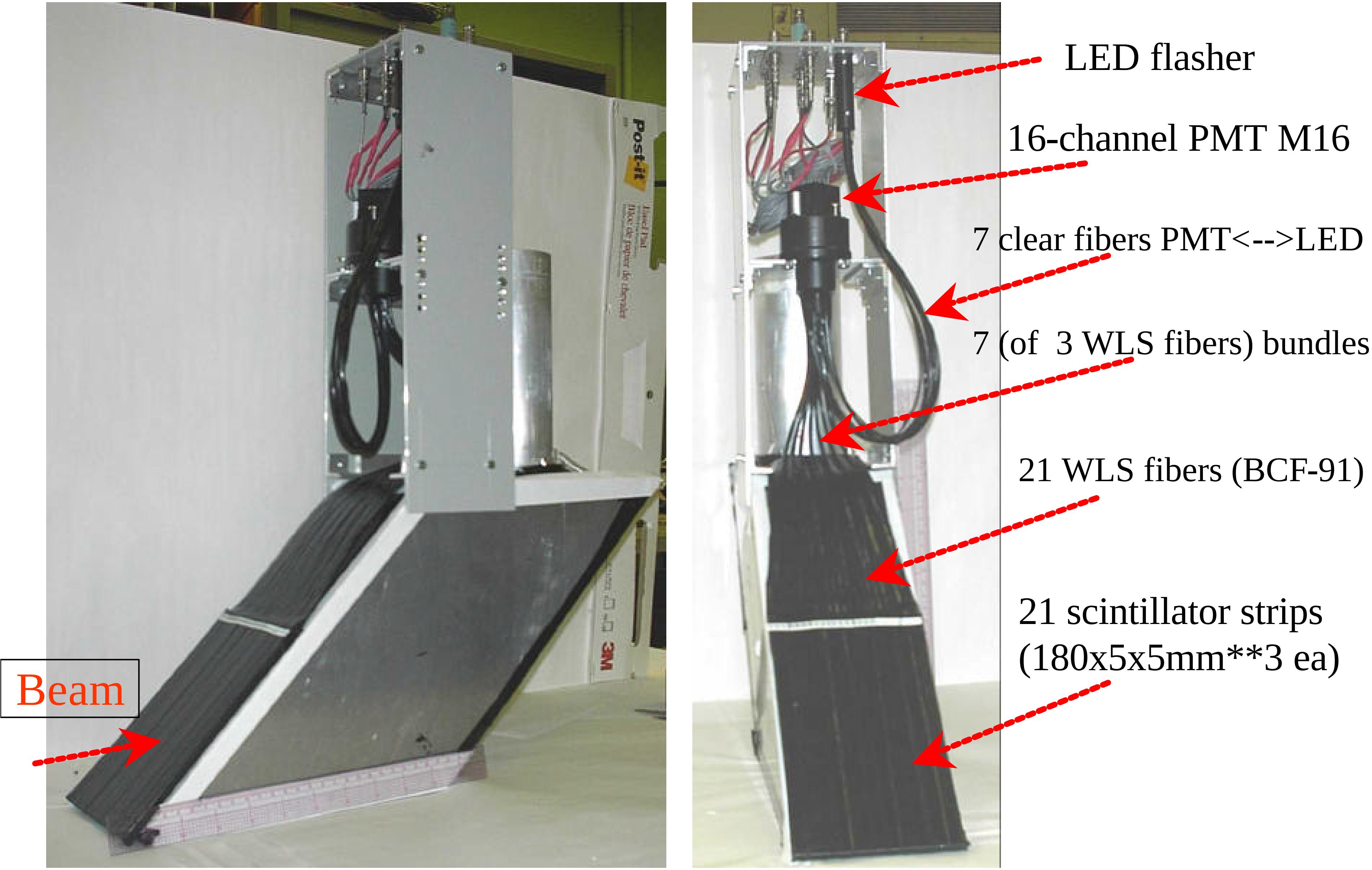


X-Y scatter plot for single neutron events in North SMD



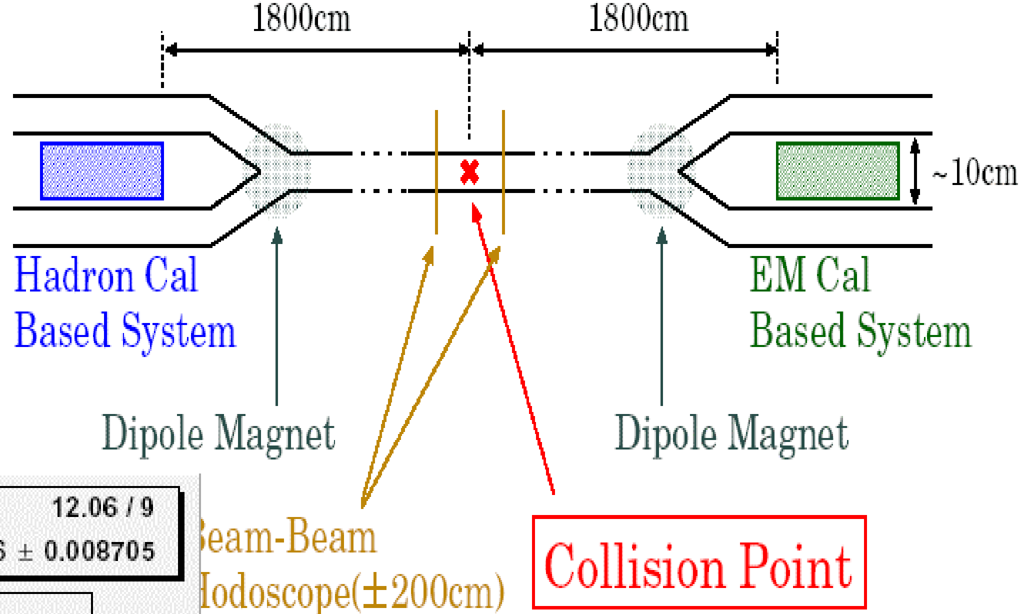


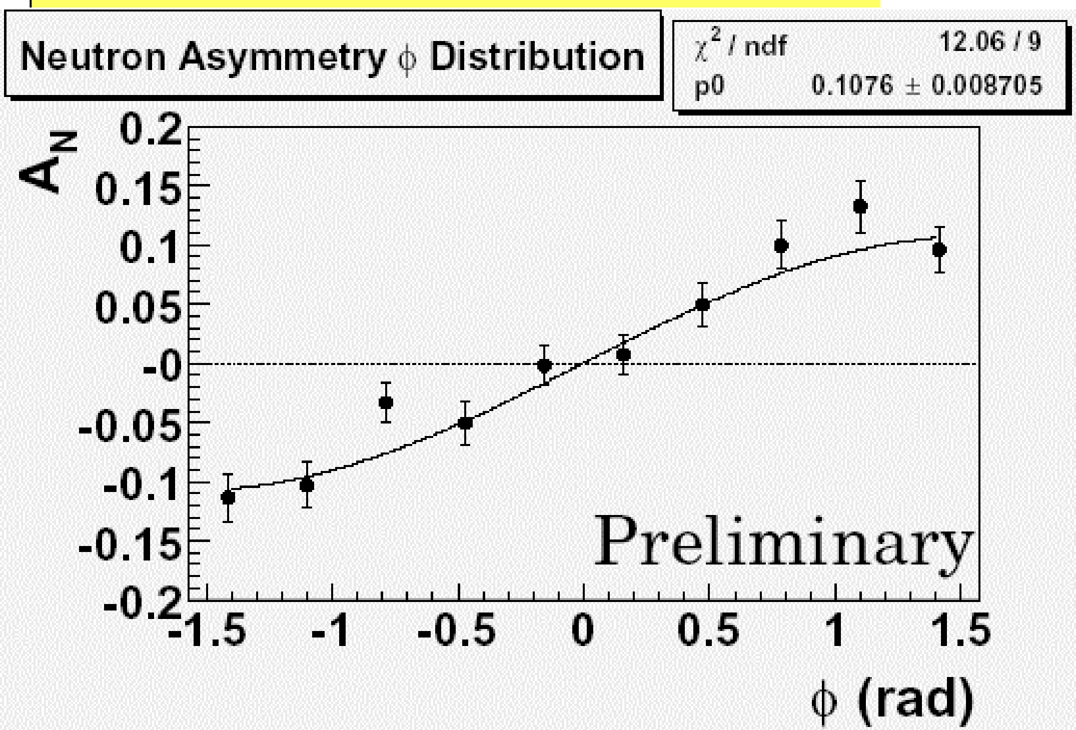
SMD assembled with a preproduction ZDC module



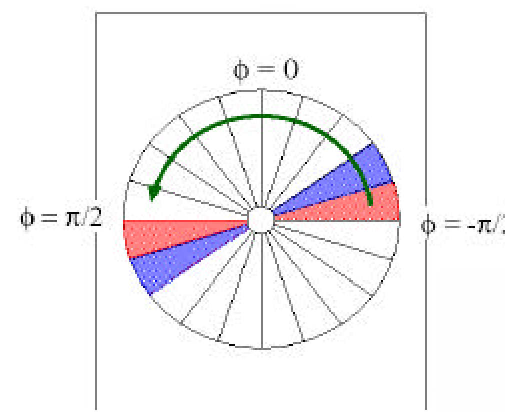
Transverse Spin Asymmetries

- Run02 IP12 experiment to look for π^0, γ asymmetries
  - Not found but they did measure a neutron asymmetry
  - Perhaps understood (?), but look for upcoming paper
- Large asymmetry gives good local (PHENIX) polarimetry.





"Left-Right" asymmetry measured for different slices in phi:



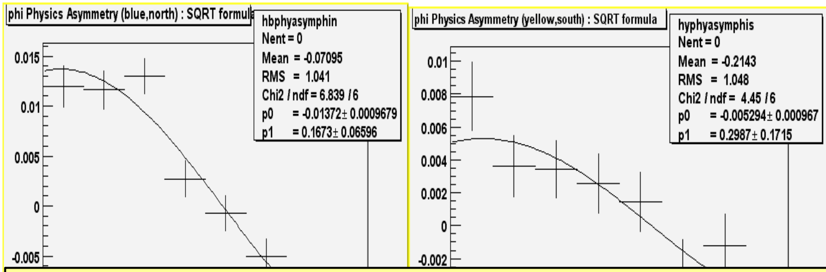
$$A_N = \frac{1}{P_B} \frac{\sqrt{N_{\uparrow L} N_{\downarrow R}} - \sqrt{N_{\uparrow R} N_{\downarrow L}}}{\sqrt{N_{\uparrow L} N_{\downarrow R}} + \sqrt{N_{\uparrow R} N_{\downarrow L}}}$$

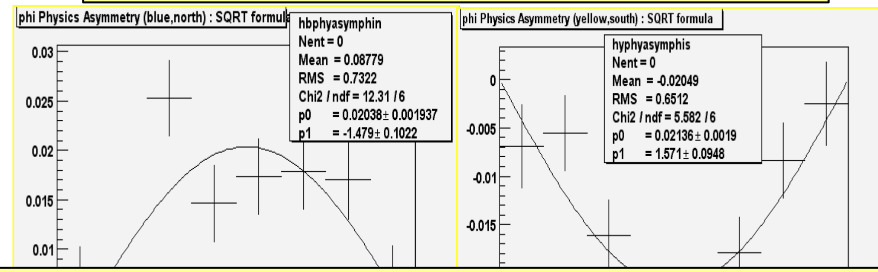
Rotator Commissioning at PHENIX

Spin Rotators OFF

Run-03

Spin Rotators ON, Current Reversed



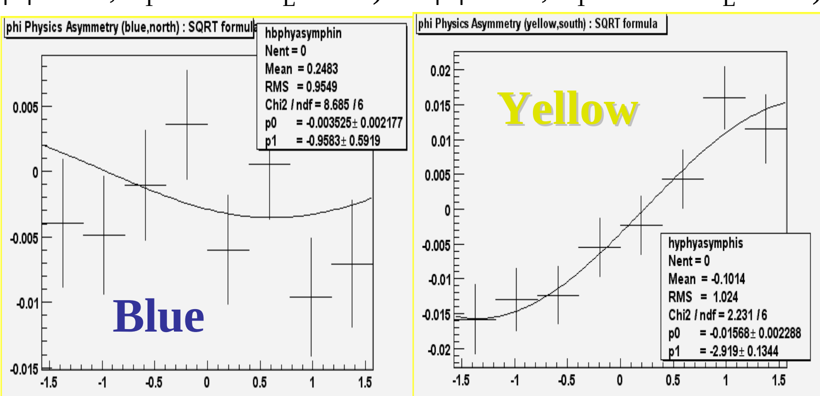


We are extremely glad that we have this local polarimeter at hand to do these checks…Without all this, our gluon polarization measurements would have been completely blind and meaningless! – Abhay Deshpande

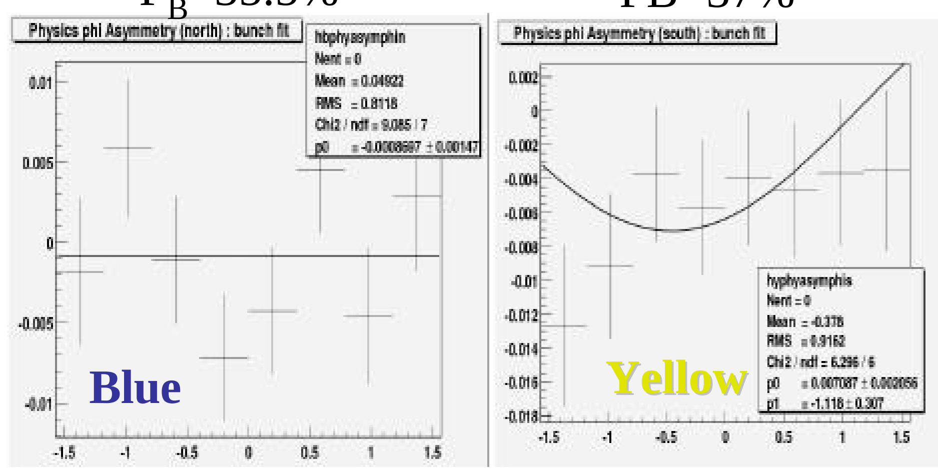
Spin Rotators ON, Almost…

Spin Rotators ON, Correct!

$|P|=30\%$, $P_T=0\% \rightarrow P_L=30\%$) $|P|=37\%$, $P_T=24\% \rightarrow P_L=28\%$)



$P_B=35.5\%$ PB=37%



Longitudinal Double Spin Asymmetries

- To determine ΔG, look at A_{LL}:

$$A_{LL} = \frac{s_{\rightarrow\rightarrow} - s_{\rightarrow\leftarrow}}{s_{\rightarrow\rightarrow} + s_{\rightarrow\leftarrow}} = \frac{1}{P_Y P_B} \frac{N_{\rightarrow\rightarrow} - RN_{\rightarrow\leftarrow}}{N_{\rightarrow\rightarrow} + RN_{\rightarrow\leftarrow}},$$

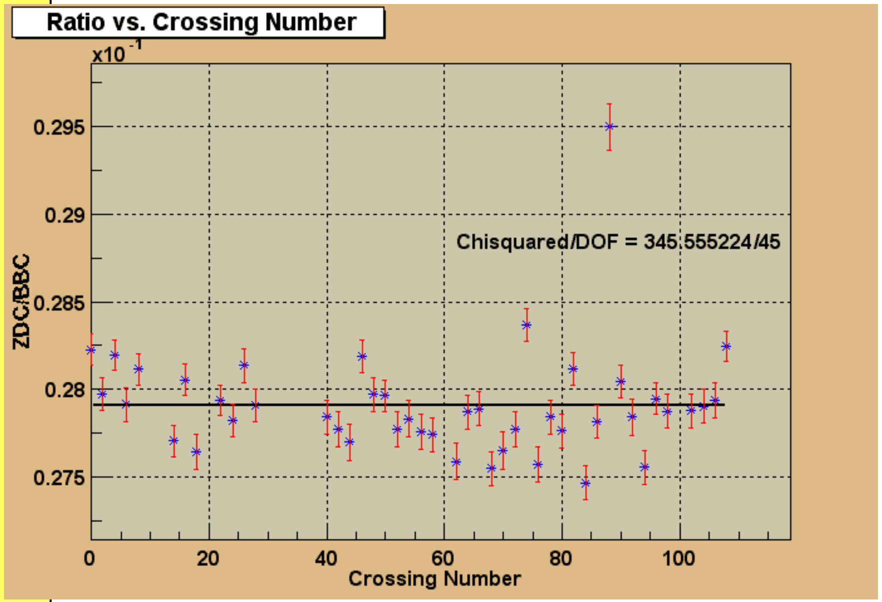
$$R = \frac{L_{\rightarrow\rightarrow}}{L_{\rightarrow\leftarrow}}$$

- R is the relative luminosity, and can be measured (to some accuracy) at PHENIX.
- Our Goal: δR/R < 0.1% for each fill
  → $\delta A_{LL} < 2\times10^{-3}$
  (expected A_{LL} for pions ~ 3×10^{-3} @P_T=3 GeV/c)

Relative Luminosity

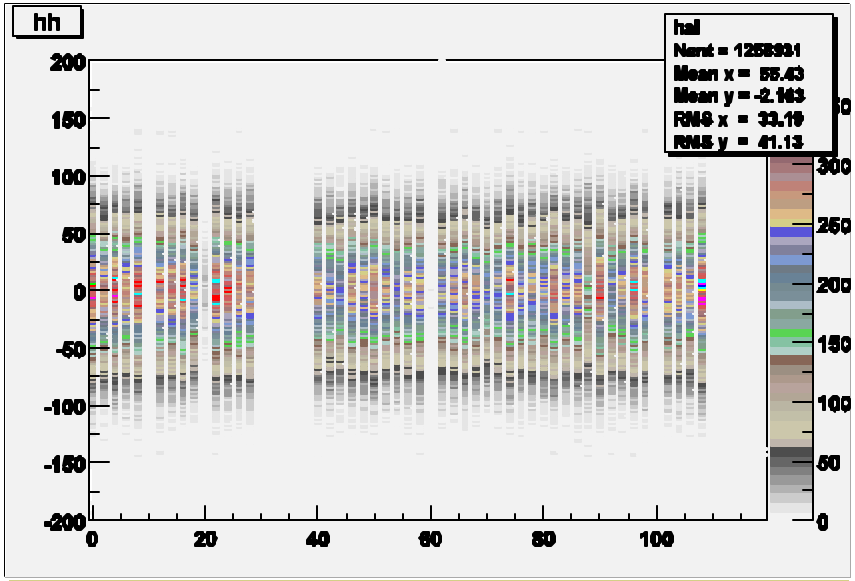
- In order to investigate our ability to measure the relative (++ vs. +-) luminosity:
  - look at ratio of 2 detector scalars crossing-by-crossing:
    - $a(i) = N_A(i)/N_B(i)$
  - Ratio should be the same for all crossings (constant) if:
    - $N_A(i) = \int L\sigma_A e_A$ and $N_B(i) = \int L\sigma_B e_B$
    - B is always BBCLL1
      A is one of the others (CH2-8).
  - Fit this by the expected pattern:
    - $a(i) = C[1+A_{LL}P_B(i)P_Y(i)]$
    - C, A_{LL} are the fitting parameters.
  - Precision of relative luminosity can be estimated by:
    - $\delta C/C$
  - If χ^2 of the fitting is bad, look for other factors in N(i).

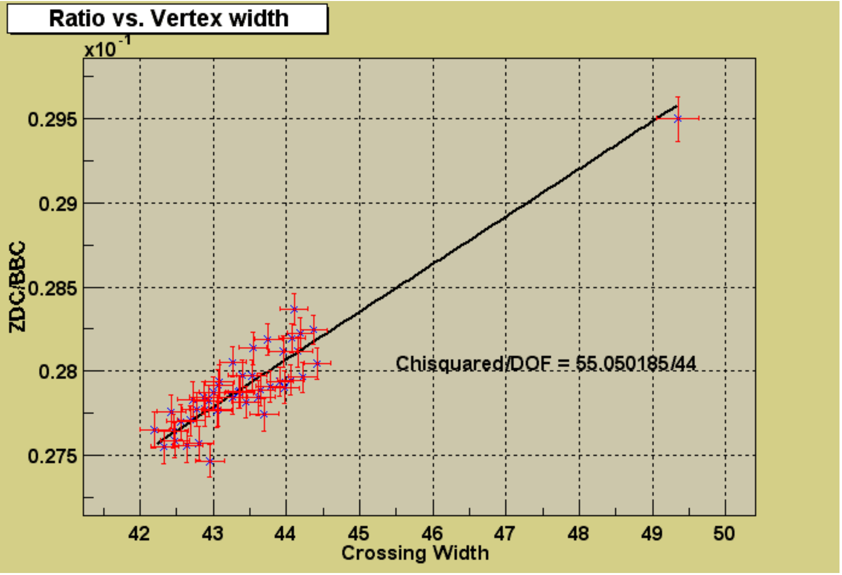
Ratio of Zero-Degree Counter scalars to Beam-Beam Counter scalars, sorted by bunch crossing and fit to a constant.



Correction Factors

- What other factors could play a role in the determination of the scalar rate besides the luminosity?
  - Vertex width
- Vertex width also measured crossing by crossing.
- Look for a correlation of the ZDC/BBC ratio with the vertex width:
  - Good correlation
- Can correct ratio for this factor.



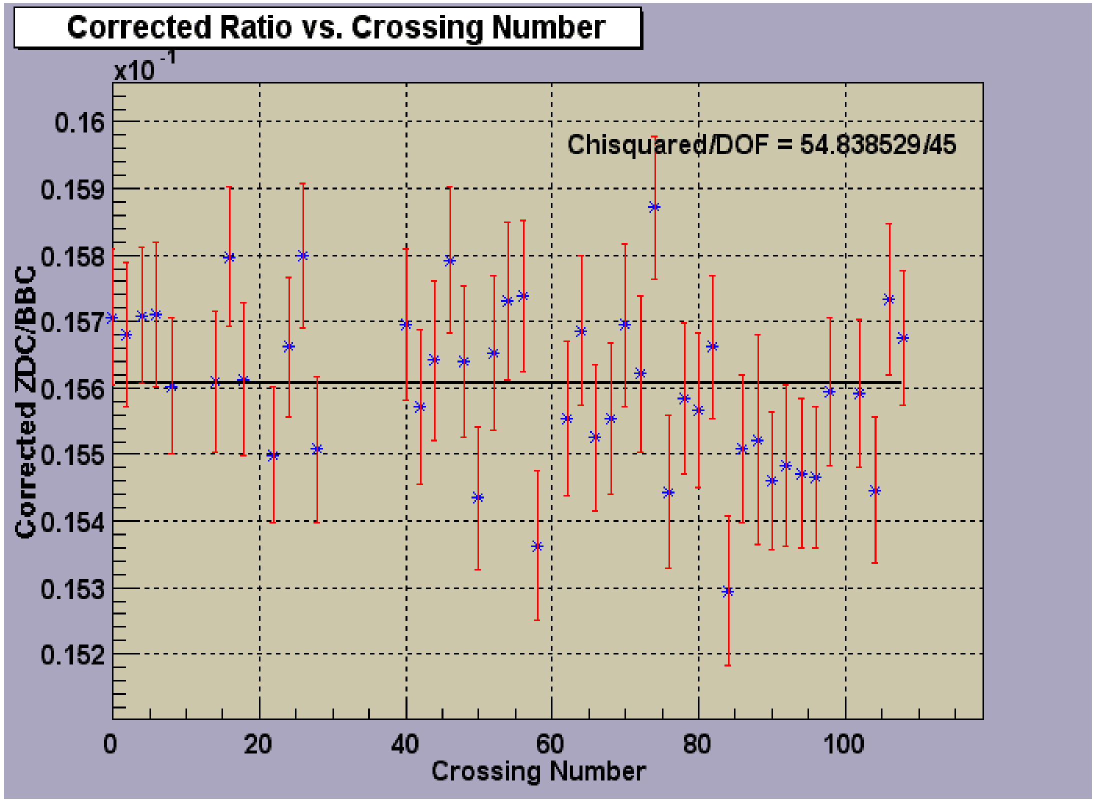


Limit on Relative Luminosity Measurement

- After correction for (measured) vertex width, the ratio of counts in the two detectors is consistent with constant up to our level of statistics
- This means that if we apply correction for this the precision on R goes from:

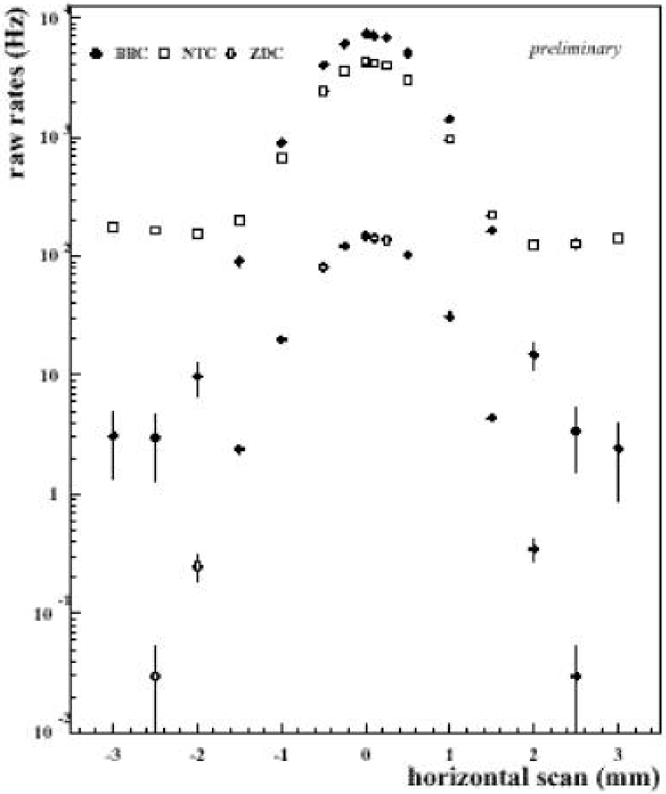
  0.11% → 0.06%

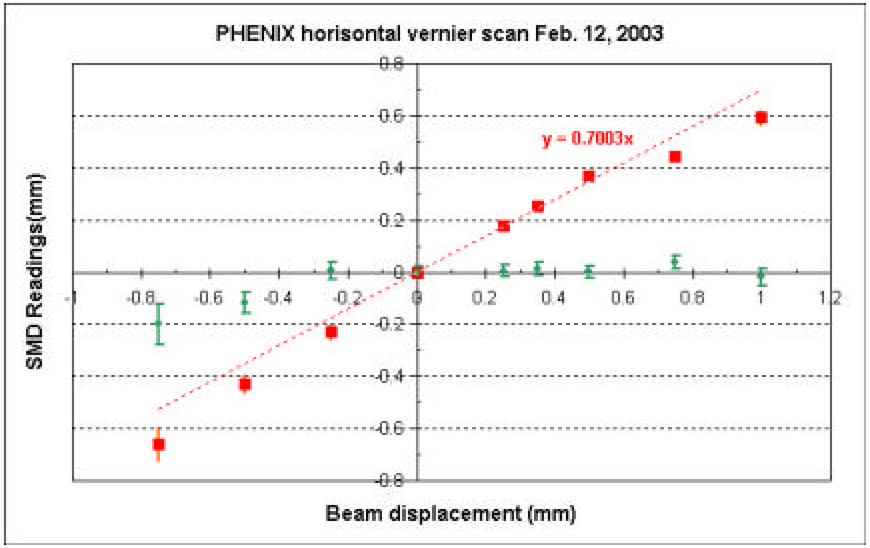
(syst. limited) (stat. limited)

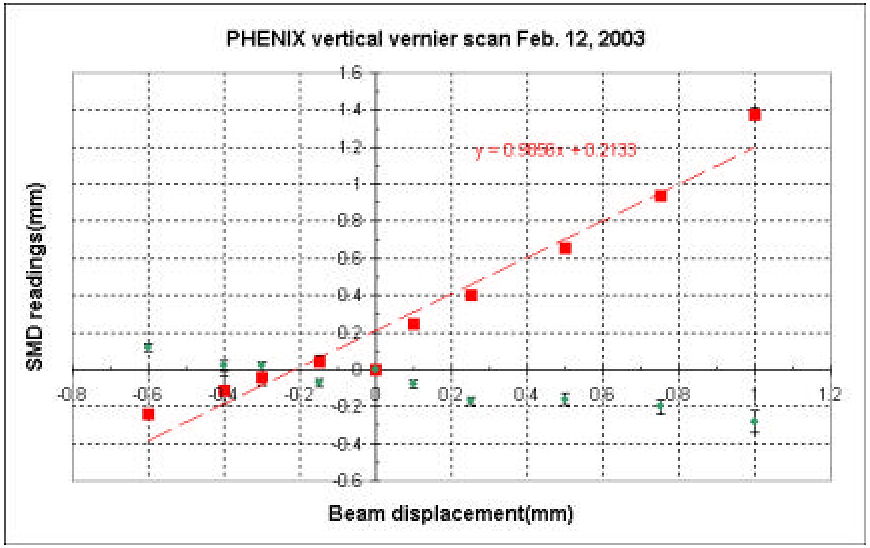


ZDC/SMD (Local Polarimeter) saved the day in two ways for the “Hot Off the Presses” PHENIX Preliminary Results for ΔG/G

Correlation between ZDC/SMD measurements and beam displacement during vernier scan

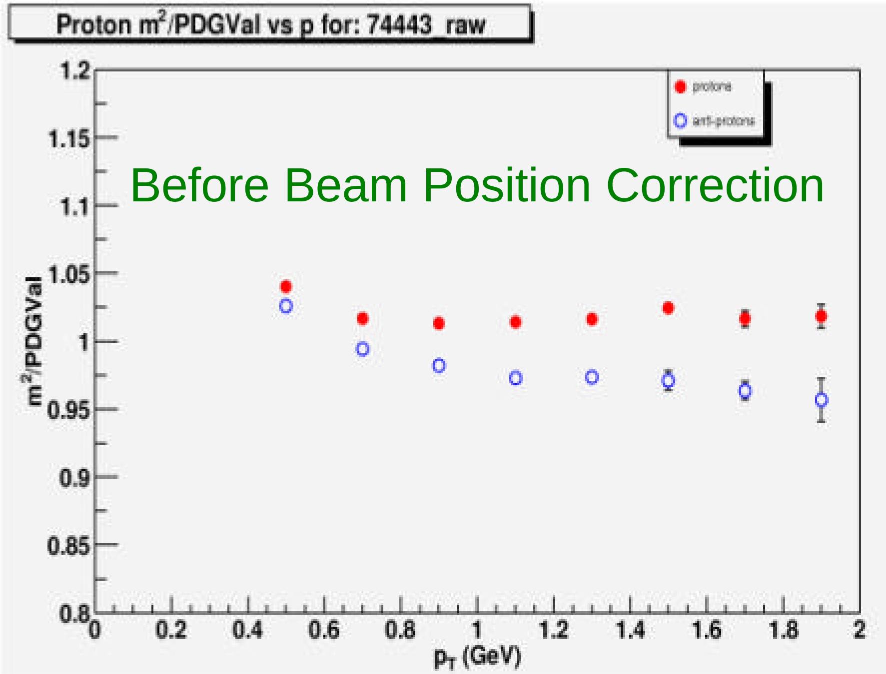


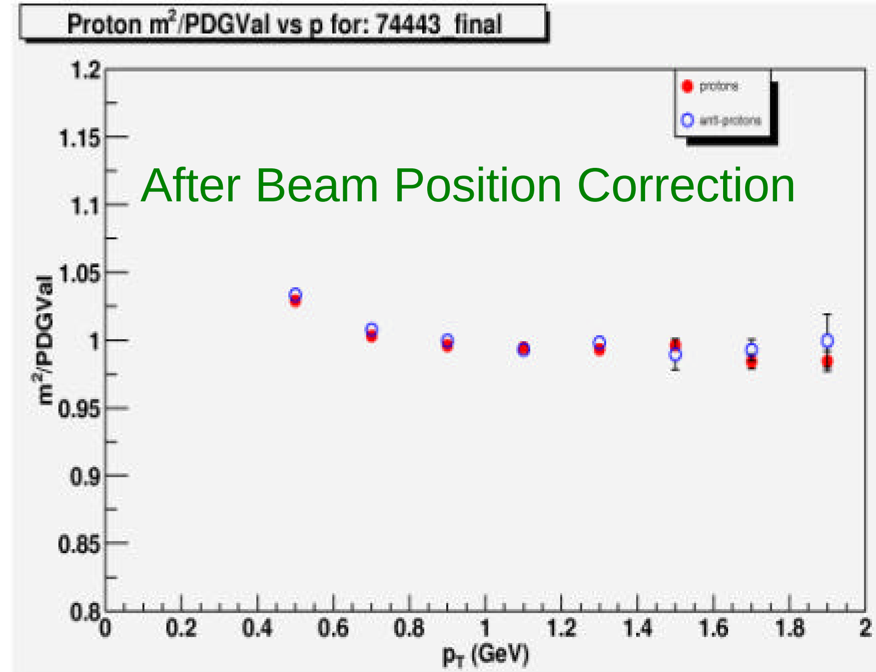




- Count Rate vs Beam Displacement
- SMD Position vs Beam Displacement

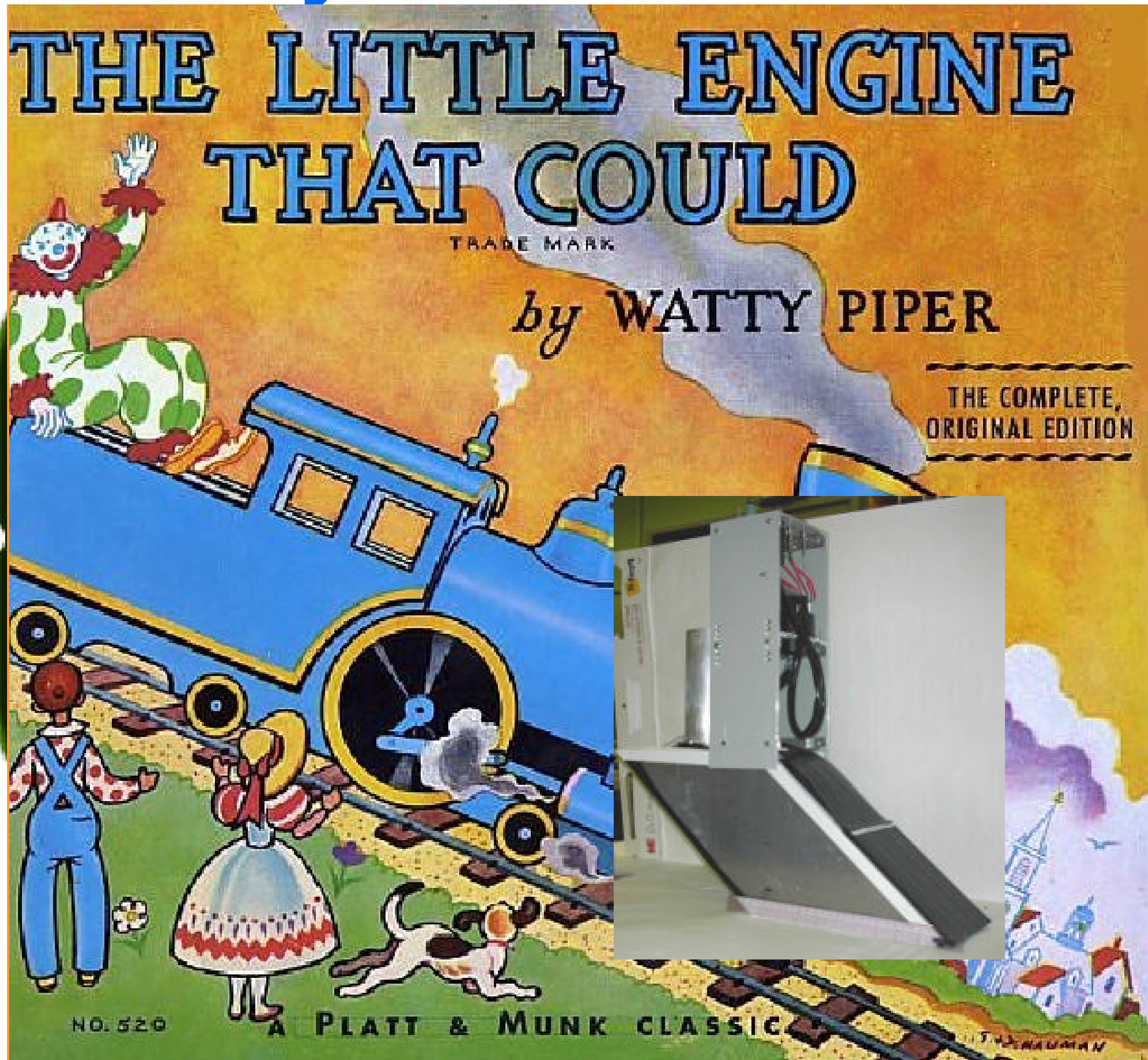
Mass Splitting Phenomenon





- Identified particles show a split in the mass^2 for positive and negative tracks
- Input to this calculation is only track angle at DC and TOF.
  - TOF is charge independent, so it must be track angle
- Beam motion measured by ZDC-SMD
- Beam x-y position correction applied.
  - Splitting gone.

Summary and Conclusions



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  - p
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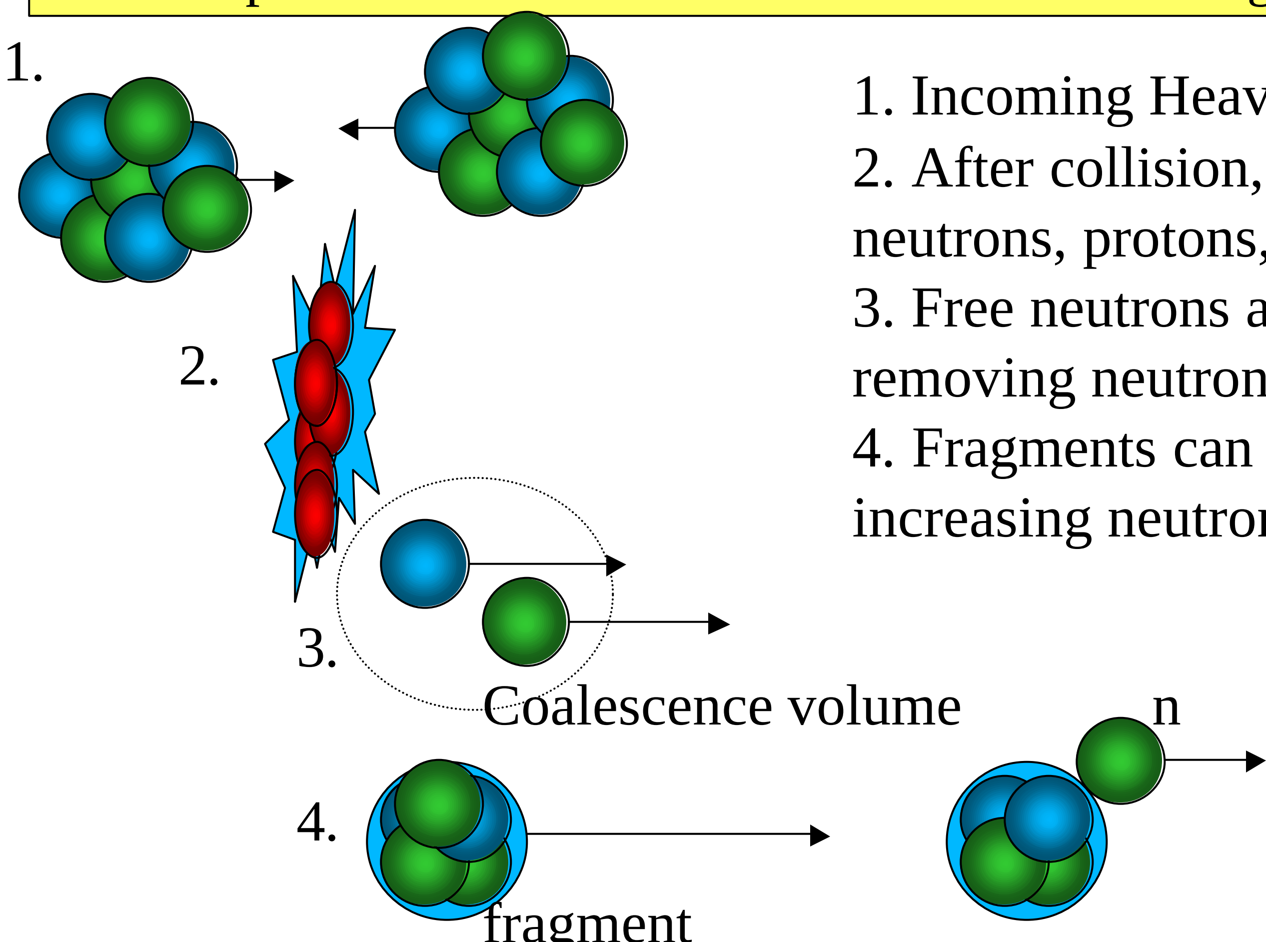
- The … IC
  - C … olliders

Backup Slides

ZDC Physics: Hadronic Interactions

- Since the ZDC sees only neutral, forward going particles, they are affected by any processes which produce or remove free neutrons
  - Coalescence of spectator nucleons into light nuclei (d, triton, alphas)
  - Evaporation of free neutrons from unstable fragments



1. Incoming Heavy Ions
2. After collision, spectators are free neutrons, protons, and fragments
3. Free neutrons and protons can coalesce, removing neutron deposition in ZDC
4. Fragments can boil off neutrons, increasing neutron deposition in ZDC